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## Semiannual Technical Summary

### ARPA Authoring System

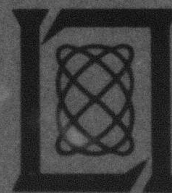
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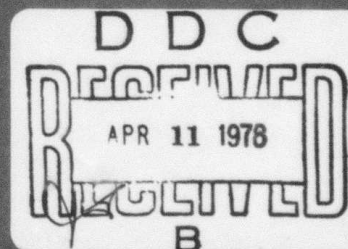
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FOR THE COMMANDER

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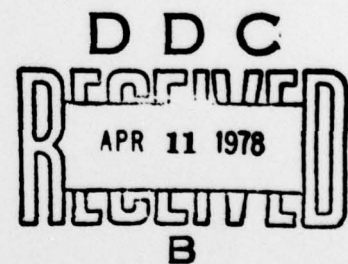
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ARPA AUTHORIZING SYSTEM

SEMIANNUAL TECHNICAL SUMMARY REPORT  
TO THE  
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

1 APRIL - 30 SEPTEMBER 1977

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# ABSTRACT

The work during this reporting period has concentrated on preparations for a full-scale test of the ARPA Authoring System in FY 78. A five-stage procedure has been developed for management of task-oriented lesson development in the on-the-job environment. It is consistent with the Interservice Procedures for Instructional System Development. It is readily adapted to other delivery systems with capabilities similar to the one of choice here, the Lincoln Terminal System, Model 5 (LTS-5). A test of evaluation procedures on task-oriented materials prepared under the Authoring System is also reported. The plan to test the system, including preparation and evaluation of materials for both maintenance technicians and technical operators, is reviewed.

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## ARPA AUTHORIZING SYSTEM

### I. INTRODUCTION

The goal of the project is to provide authoring procedures that enable subject matter experts to prepare lesson materials for use in on-the-job training. The following conditions prevail:

- A subject matter expert, as opposed to an instructional expert, is the primary author of the material.
- Substantial training and guidance is given to authors on computer facilities.
- Materials are designed for delivery by a computer-based system.

The lesson preparation procedures are consistent with the course design principles underlying the Interservice Procedures for Instructional Systems Development.\*

The area of application chosen involves experts in technical operations who serve as authors because acquisition of subject matter expertise through field experience is essential. Currently, bridging the gap between formal knowledge and actual readiness to perform complex tasks is achieved by a master/apprentice training relationship. It is a costly method and the shortage of qualified trainers is often a limiting factor. There is a need to provide a substitute for live training. The solution proposed is to use new authoring procedures developed especially for this application area to capture the know-how of the technical expert in materials for timely delivery by machine.

The approach, described in the previous Semiannual Technical Summary,<sup>†</sup> involves procedures for authors that are based on a prototypical lesson design, one that mimics the master instructing the apprentice. Because the target population for task-specific training is often small, authoring must proceed smoothly and rapidly to justify the expenditure of technical talent. The author must have knowledge of the procedures, operational requirements, principles, facts, etc., directly useful in task performance. A modest capacity for exposition and experience in one-on-one training are helpful, but the procedural approach to authoring greatly reduces the need for the expert in the subject matter to qualify as an expert in educational strategy and technique as well.

In order to employ the authoring procedure, it is necessary to embed it in a training development system appropriate to the context and goals of on-the-job environments. One difficulty is that the usual procedures are tailored to the resources and management organization of centralized, dedicated training facilities; at the work site, training is part of the work management system and, since qualified technicians serve as authors, it is appropriate that lesson development be done within the same organization. Such an arrangement is likely to make training more responsive to the needs of work performance. Another difficulty arises if there is total reliance on the usual ISD (Instructional System Development) procedure which analyzes tasks

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\*Interservice Procedures for Instructional Systems Development, TRADOC Pamphlet 350-30, U. S. Army (1 August 1975).

† ARPA Authoring System Semiannual Technical Summary Report, Lincoln Laboratory, M.I.T. (31 March 1977), DDC AD-A044794.

**TABLE I**  
**SUMMARY OF THE STAGES OF LESSON DEVELOPMENT**  
**WITH ESTIMATES OF DURATION AND MAN-HOURS**  
**(Based on Preparation of Materials to Support One Hour of Training)**

**STAGE 1 – TRAINING PROGRAM PLANNING**

Location	Work Site	
Product	List of Lesson Topics	
Duration	1 to 2 (days)	
Personnel	Work Manager	1 (man-hours)
	Training Manager	1

**STAGE 2 – LESSON SPECIFICATION**

Location	Work Site	
Product	Lesson Specification	
	Lesson Validation Plan	
Duration	2 (days)	
Personnel	Author	4 (man-hours)
	Technical Advisors (2)	8
	LTS Advisor	4
	Training Manager	4

**STAGE 3 – LESSON PREPARATION**

Location	Authoring Center	
Product	Lesson in Draft Form	
Duration	30 (days)	
Personnel	Author	90 (man-hours)
	LTS Advisor	15
	Technical Advisor	4
	Trainees	3

**STAGE 4 – CONVERSION TO MEDIUM**

Location	Authoring Center, Fiche Production Facility	
Product	Lesson on Microfiche	
Duration	30 (days)	
Personnel	Author	4 (man-hours)
	Artist/Typist	32
	LTS Technician	8
	Photo Technician	20

**STAGE 5 – LESSON EVALUATION**

Location	Work Site	
Product	Lesson Revisions	
Duration	10 (days)	
Personnel	Author	8 (man-hours)
	LTS Advisor	8
	Technical Advisors (2)	8

into component skills for subsequent training. Instruction on component skills is a necessary but not sufficient condition for preparation of the technician or operator for work. It is not a substitute for hands-on training because many details and the relevance of basic facts and concepts are not adequately covered. In task-oriented training, the relevant skill knowledge, however fragmented, is presented at each step of the task. Training in general areas of skill knowledge is presumed and the presentation is in the form of a review of related technical matters. As a consequence of these differences, the ISD procedures must be adapted to the production of task-oriented training materials.

A set of appropriate management procedures is presented in the next section that includes the authoring procedures previously developed. In the following section, a report of a formal evaluation of a lesson developed under the authoring procedures is made; it constitutes a demonstration of a methodology for Stage 5 of the materials development system, Evaluation of Training Effectiveness. Finally, a test plan is outlined for a full-scale evaluation of the system in FY 78.

## II. MANAGEMENT PROCEDURES FOR TASK LESSON DEVELOPMENT

### A. Overview

A five-stage procedure has been prepared for the development of task lessons in the on-the-job environment. The system of materials preparation is tailored to meet three objectives: first, to provide the work manager and his technical staff with control of the materials preparation effort; second, to make efficient use of qualified experts in lesson preparation; and, third, to streamline the authoring process so that the turnaround time for a lesson product is short.

The result of each stage is a specific intermediate product along the path of lesson development. The five stages are:

- (1) Planning a training program.
- (2) Preparation of a lesson specification.
- (3) Preparation of a lesson in draft form.
- (4) Conversion of the materials to appropriate medium.
- (5) Evaluation of training effectiveness.

Two kinds of records are maintained on a routine basis; one indicates the efficiency of the lesson development process and the other the effectiveness of the final product. Data are gathered at each stage to bring to the attention of the training system manager any source of difficulty or delay in authoring. The information includes total man-hours, total calendar days to completion, and quality of the product at each stage. Effectiveness is evaluated at Stage 5 on the basis of student records gathered during training. Eventually, the work manager executes the lesson validation plan prepared in Stage 2 to determine whether lessons have the desired effect on work performance.

The stages are reviewed in Table I; it includes the locale, product, duration, and manning for a typical case. It is assumed here that the medium for training is the LTS-5,\* but the procedures apply to any other medium with similar capabilities.

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\* "The LTS-5, A Brief Description," Technical Note 1977-13, Lincoln Laboratory, M.I.T. (16 December 1977).



#### B. Stage 1 - Training Program Planning

The product of this stage is a description of an area of work performance that is the topic of one or more lessons. Steps at this stage are:

- (1) Select topic.
- (2) Set lesson objectives.
- (3) Define the instructional setting.

The assumption is made that the description of the tasks that make up the job have already been established according to ISD methodology, e.g., Phase I of the Interservice Procedures. At this point the team selects those topics related to important work problems that are appropriate for task-oriented training.

#### C. Stage 2 - Lesson Specification

The products of this stage are a lesson specification and a plan for lesson validation. The procedure is:

- (1) Prepare a lesson validation plan.
- (2) Form a work team of subject matter experts.
- (3) Identify the significant work problems.
- (4) Write the lesson objectives.
- (5) Identify typical work sequence(s).
- (6) Review the lesson specification.
- (7) Select a team member as author.

Validation of a lesson requires monitoring of work performance under controlled conditions. Evidence of the quality of performance is based on time to complete tasks, quality of result, assessment of the possibility of equipment damage, and the amount of supervision and assistance required. An important aspect of the validation is to check performance on closely related tasks. These checks are particularly relevant to task lessons since the purpose of including explanations is to promote generalization to various working conditions.

The process of lesson specification is to generate the information listed in Table II. The team includes the author candidate and two or three other subject matter experts. Operational personnel know the work requirements but cannot be expected to be aware of all aspects of lesson planning and validation; thus, an educational specialist, in this instance the "LTS Advisor," is also present to assist in matters of lesson design and planning. The author is a member of the team and thus is prepared to deal with minor oversights in the lesson specification in later stages. In fact, the quality of the product is judged in part by the incidence of referrals back to the team for clarification.

#### D. Stage 3 - Lesson Preparation

The major product of this stage is a draft lesson in notebook form. The notebook contains all the basic information in the lesson, explanations and procedures, as well as provision for means to test understanding and task performance. For LTS-5 delivery, this means rough visuals, an audio tape segmented by frames, and interactive frame logic. The notebook version of the lesson is reviewed by the other subject matter experts on the team, it is tried out on a

TABLE II ENTRIES IN THE TASK LESSON SPECIFICATION FORM	
1. Course Title	4. Medium
2. Topic Area	5. Objectives
3. Training Conditions	6. Work Problems
Trainee	7. Typical Work Sequence(s)
Prerequisites	8. Related Documents
Location	9. Lesson Title(s)
Mode (hands-on, simulated)	10. Validation Plan
Aids	
Trainer	
Equipment	
Documents	

few trainees, and it is revised if necessary. It remains unchanged thereafter until it has been evaluated in the training environment.

The procedure for this stage is:

- (1) Prepare outline and flowchart.
- (2) Prepare frames.
- (3) Team review.
- (4) Tryout with trainees.
- (5) Notebook revision.

The first two steps constitute the task lesson [formerly TPI (Task Procedure and Interpretation)] authoring procedure. The outline defines the steps in the task and the flowchart represents the organization of the frames. The team reviews the notebook, judging whether the content is adequate to meet the lesson objectives set down. Two or three trainees drawn from the target population are used in the lesson trials. The author administers the lesson one-on-one, simulating the functions normally performed by the LTS-5 or other delivery system.

The lead roles throughout this stage are played by the lesson author and the LTS Advisor. While the identity of the individuals in other roles may change in the course of lesson development, there must be a single, responsible author. Any other arrangement is likely to result in an excessive rate of modification of the lesson, leading to prohibitive delays and costs. Also, to be efficient, the author's effort must be a continuous one, largely free of interruptions. The LTS Advisor is on call during this stage to answer the author's questions and to comment on design problems, strategies, objectives, etc. The Advisor resolves any issue concerning media, the authoring process, and the lesson structure. As an expert on the form of lessons but not usually on the subject matter, the Advisor does not normally comment on the content. The author is the final judge of what revisions are to be made as a result of the peer review and the lesson trials. While all information becomes part of the record – it may be of value for later revisions – it is the author, assisted by the other experts and the LTS Advisor, who prevails.

#### E. Stage 4 - Conversion to Medium

The product of this stage is a set of finished materials for LTS-5 delivery. The procedure is:

- (1) Prepare graphic displays.
- (2) Record audio.
- (3) Prepare and check frame logic.
- (4) Send materials to fiche production facility for conversion.

Materials conversion must run smoothly to avoid turnaround delays. The steps in the overall procedure unique to the LTS mode of delivery are mostly in this stage.

#### F. Stage 5 - Lesson Evaluation

The product of this stage is a task lesson ready as a substitute for one-on-one live instruction in on-the-job training. Some errors in form or content may be found in the first version and some revision may be necessary. Under normal circumstances a good result may be expected, as long as the task procedure and the lesson in draft form had previously been tried on a few trainees.

The procedure is:

- (1) Check finished material.
- (2) Run lesson in training on a trial basis.
- (3) Collect and analyze training data.
- (4) Revise lesson as required.

The author first checks the final copy to be certain that the lesson is free of technical errors. The material is used in the training program using the normal training procedures, and a record is kept of the amount and kind of assistance given by the work supervisor. Comments by the trainee, tests before and after training, and other information may also be obtained.

Lesson evaluation is based on the dwell time on information frames and error rates on the quizzes contained within the lesson. On the LTS-5 these data are recorded on cassette tapes that are analyzed subsequently on a small, general-purpose computer. These data indicate areas of the lesson that may require improvement. Thus, short dwell times may show the need to combine frames and long ones to add new ones. Excessive use of Help and corrective frames suggests a need to incorporate more information in the main line of the lesson or in the prerequisite training. In general, objective evidence should carry much more weight in the decision to modify lessons than peer review, a rule that minimizes polishing of lessons that has little return in terms of training effectiveness.

#### G. Further Evaluation

As a follow-on, the training manager will execute the lesson validation plan made in Stage 2 and gather evidence on the extent to which training improves work performance. The assessment of these results by the work managers is, of course, the ultimate criterion.

Records of the man-hours of the author, LTS Advisor, and other participants and of the elapsed time for each stage are maintained. These data may be compared with standards of lesson development efficiency, such as suggested in Table I, to identify areas of difficulty. Factors that will affect the numbers include the experience of the author in preparing materials,



expertise of the author in the topic area, and the need for extensive explanation of procedure in the lesson. Provision of a system for close monitoring of the lesson production process is consistent with the ISD requirements and philosophy.

### III. AN EXAMPLE OF TASK LESSON EVALUATION

An example of an evaluation of a task lesson, as specified above in Stage 5 of the lesson development procedures, is presented here.

#### A. Description of the Lesson

A formal test has been conducted of a task lesson reported in the previous Semiannual Technical Summary Report. It was described there in Table I as a TPI under the brief title "Voice Circuits of AN/TRC-97A." The lesson was authored by a Senior Airman from the 5th Combat Communications Group at Robins AFB, Georgia, with the procedures developed under the contract.

The subject matter is the "initial setup and alignment of the AN/TRC-97A Radio Set multiplexer and installation of the order wire." There are 45 frames in all of various kinds. Nine are introductory. Nineteen are concerned with explanations: 6 main line, 3 Help (auxiliary information), 5 test, and 5 remedial frames. Seventeen are task related: 9 main line, 4 Help (detailed instructions), and 4 task evaluation frames.

#### B. Test Procedures

Several tests were designed to evaluate the effect of the lesson on skill knowledge and work performance. The Prerequisite Test consisted of 19 multiple-choice items to test basic knowledge of multiplexers, receivers, transmitters, and the concepts of signal and noise. The test was made up of "easy" items because only an elementary knowledge is required. The Skill Knowledge consisted of 27 items on facts and concepts that might be acquired during the course of the lesson. The Performance Test was made up of two problems; each problem was solved in a number of steps and lead to the identification and correction of a system fault. The performance was not hands-on to the AN/TRC-97A, and the tasks were simulated on the LTS-5 instructional unit. An eight-item attitude survey was also given.

The test of the lesson was preceded by familiarization training. This training on the AN/TRC-97A consisted of rehearsing some of the same routine tasks done in the test lesson but without explanation of relevant concepts. Approximately one week later the main test was conducted. First, the trainee was administered one form each of the Skill Knowledge and the Performance Tests. The lesson was presented next, followed by the other form of the Skill Knowledge and Performance Tests and by the survey. The lesson was hands-on to the Radio Set. To exercise the task instructions, the equipment was configured to simulate field conditions and a few misalignments were set into the machine ahead of time.

The trainees consisted of both recent technical school graduates and experienced personnel not familiar with the AN/TRC-97A. There were 25 in all from the 2nd and 5th Combat Communications Groups at Patrick and Robins Air Force Bases.

#### C. Results

The median scores on the Prerequisite Test were about 70 percent for novice technicians and 90 percent for experienced ones. The lowest score was 60 percent in both groups. These

data suggest that there is substantial learning of basic concepts in the job environment. The results of the pre- and post-test of Skill Knowledge show a median gain of about 40 percent over all trainees, an illustration of how performance training enhances skill knowledge learning, of both procedures and facts and concepts in the explanations that accompany the task instructions.

The purpose of the performance test was to assess the impact of the lesson on execution of closely related tasks, troubleshooting in this case. No gain or loss was observed on the average. The general conclusion of the test results is that there appears to be learning of skill knowledge in the job environment, but the learning here was not sufficient to promote generalization to the other tasks.

The LTS Advisor reviewed the data obtained on the LTS cassette tapes during training and identified one or two places where the explanation of important concepts was accompanied by long frame dwell times and by errors on the test frames that followed. As a result, it was recommended that a few frames be revised and that the concept of the system block diagram be covered in training prerequisite to this lesson.

#### IV. FIELD TEST AND EVALUATION OF THE AUTHORING SYSTEM IN FY 78

A full-scale test of the authoring system is planned for FY 78. The effort is part of a training improvement program within the Tactical Communications Area of the Air Force Communications Service. It involves subject matter experts as authors from the 2nd and 5th Combat Communications Groups, Air National Guard, and Area headquarters. The principal application is in the training of Radio Technicians, the 304X0 Air Force Specialty Code, on maintenance of the AN/TRC-97A Radio Set. A follow-on effort will be conducted in training Radio Operators, the 307X0 Code, on operation of the AN/TSC-62 Communications Van.

The authors will prepare training materials working within the system. The lessons will be incorporated in the regular program of training and evaluated. Thus, the effectiveness of the authoring system will be assessed in terms of the quality of the products. Formative evaluation of lessons will be done using the data from 10 to 12 trainees collected on the LTS-5 cassette tape. Stage 2 of lesson development includes specification of a lesson validation plan; an attempt will be made to have this plan executed for each lesson and the results interpreted.

It will be recalled that the management procedures include monitoring the efficiency of the lesson production process. Two measures are of primary significance, man-hours and elapsed time. A record of man-hours, broken down by work roles, provides a basis to estimate the cost of lesson development in terms of dollars or, more importantly, in terms of demand for scarce resources. A record of elapsed time, calendar days for each stage plus the delays between, is a measure of the responsiveness of training to the need to correct work performance problems.

In the field test, there will be three major parameters: lesson complexity, lesson preparation experience of the author, and subject matter expertise of the author. Complexity of a task lesson is defined in this context as the amount and sophistication of the explanatory material that accompanies the task instructions. At one extreme is the pure procedure, no more than a Job Performance Aid with task evaluations interspersed; at the other is the task lesson with extensive interpretation. The second parameter, authoring experience, makes a distinction between the subject matter expert's first and subsequent efforts. Finally, level of expertise refers to whether the author is regularly engaged in exercise of the tasks or is familiar with them only on the basis of past experience. The measures of the effects of these parameters

will be in terms of data such as that in Table I, man-hours and elapsed time for each Stage. Favorable conditions are assumed, i.e., the task procedures are well established, the lesson is moderate in complexity, and the authors are qualified experts and have written at least one lesson before. The figures in Table II will be refined as a result of the field tests.

The primary field test will be conducted on lessons on the AN/TRC-97A and authoring operations will be centered at the 5th Combat Communications Group. Thirty-two lessons, averaging  $\frac{3}{4}$  hr each, will be prepared. Lessons will fall into three categories: Preventative Maintenance Checks, Equipment Alignments, and Operations. The last category is a miscellaneous one, which involves subjects such as Interface Criteria, Aligning Antennas with a Pocket Transit, Anti-Jamming Procedures, etc. Some lessons planned are largely procedural; most depend on extensive explanations. Sixteen authors will each prepare two lessons. Most are actively engaged in doing the prescribed tasks; others are technical support personnel. Thus, a mix of conditions will prevail that will permit an assessment of the effects of the main variables - complexity, authoring experience, and level of expertise.

The authors are given substantial administrative and technical support. They are held accountable for their work by senior members of the authoring team who are experienced trainers and are not likely to permit lessons with serious flaws to be committed to final form. As a result, it is anticipated that adverse effects will appear in the management data rather than the training data - specifically in man-hours and duration of Stage 3, Lesson Preparation itself.

The other area of lesson development, operation of the AN/TSC-62 Van, is of special interest because of the emphasis on the operator as trainee, as contrasted to the technician. There is a shift of emphasis toward memorization of complex procedures and away from problem solving that is characteristic of maintenance work. That is, understanding the tasks helps the operator to remember the procedures and permits checking each step to determine if it "makes sense." To the technician, understanding means having facts and concepts available that enter into a reasoning process that leads to the detection and correction of system faults. Presently, there is a need to modify the authoring procedures in a few places to accommodate the requirements for operator training. The activity in the area will be centered at the 2nd Combat Communications Group and will serve to broaden the test of the utility of the task lesson development procedures.



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